# Superposition with Phasors (take 2)

## EE 206 Circuits I

**Jake Glower**

**03/19/20**

Please visit Bison Academy for corresponding lecture notes, homework sets, and solutions

## Superposition (take 2)

Superposition allows you to analyze circuits with multiple sinusoidal inputs. If this is the case

- Treat the problem as N separate problems, each with a single sinusoidal input.
- Solve each of the N problems separately using phasor analysis
- Add up all of the answers to get the total output.

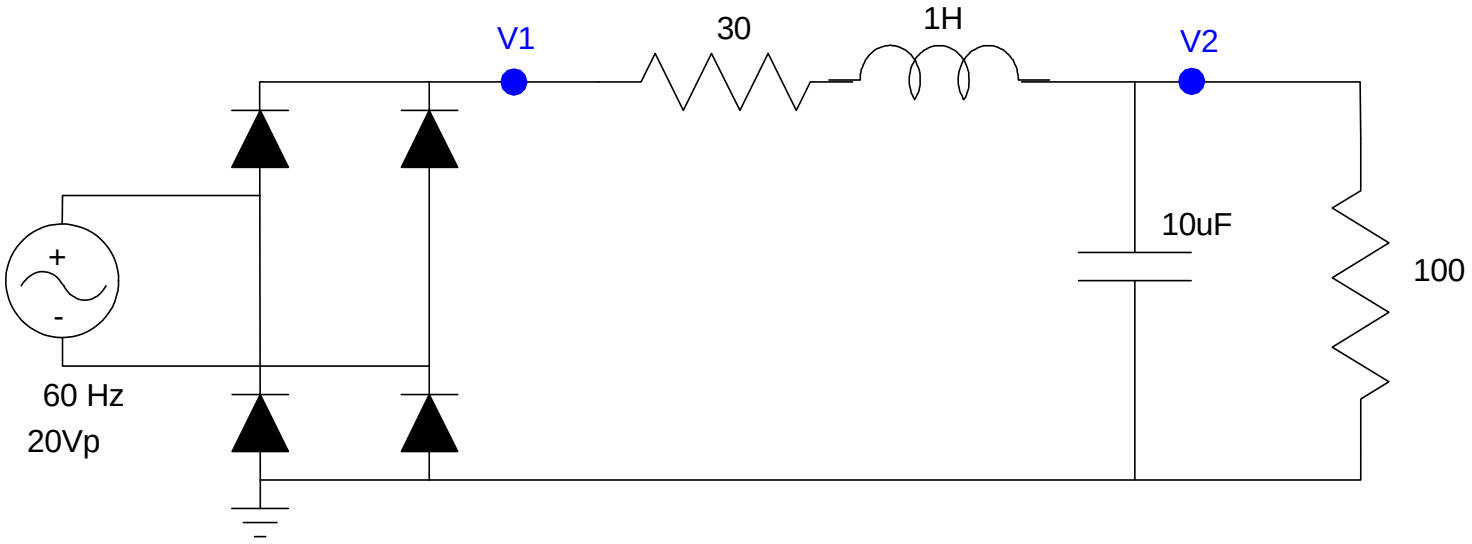
## Problem:

Suppose your circuit has an input that $sn\ t$ a sum of sinusoids. A typical engineering solution is to change the problem so that the inputs $r$ sinusoids. The trick is you want to change the problem so that

- It is solvable (a big plus), and
- It keeps the flavor of the original problem.

# Example 1: AC to DC Converter

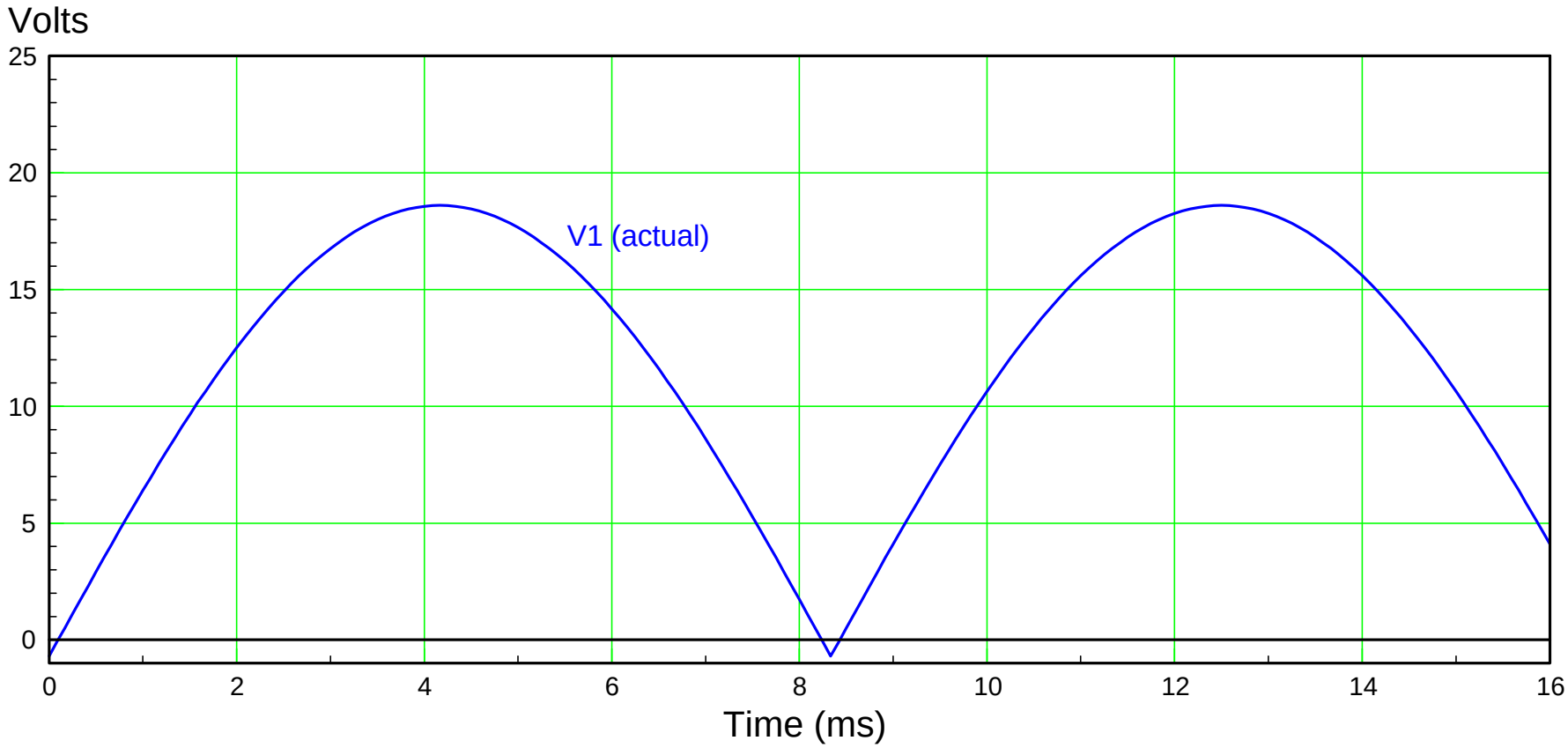
The following circuit is an AC to DC converter that we'll cover in ECE 320 Electronics I. Determine the voltage at V2:




AC to DC Converter covered in ECE 320 Electronics I

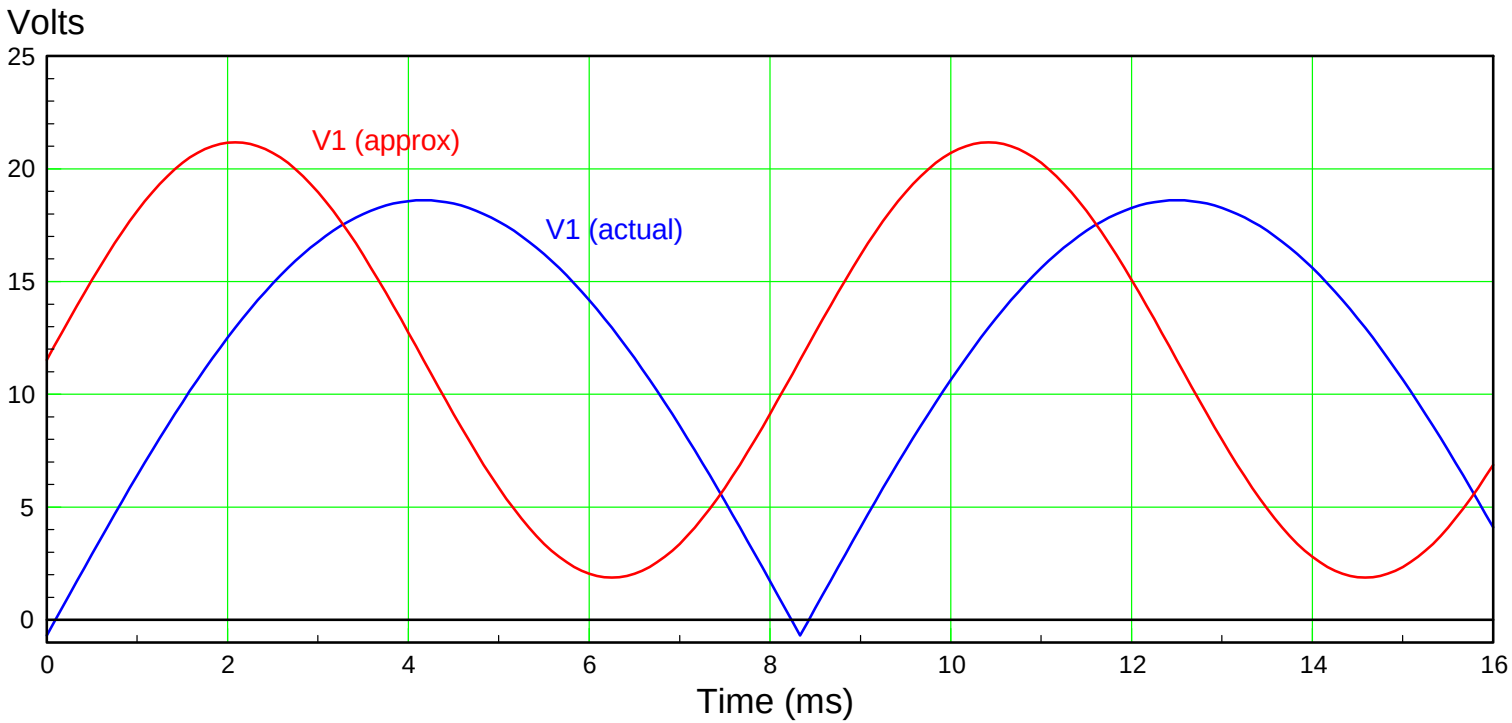
# Problem: V1 isn't a sine wave

$$_1 \approx \left|19.3 \sin(754t)\right| - 0.7$$



Change the problem:

- The DC level of V1 is 11.31V
- The frequency of V1 is 120Hz (754 rad/sec)
- V1 = 19.3Vpp



## Solve usine Superposition

$$_1(t) = 11.31 + 9.65\cos(754t)$$

DC Analysis: The capacitor is open and the inductor is a short. By voltage division

$$X = 11.31 + 0$$

$$\omega = 0$$

$$_2 = \left[\frac{100}{100+30}\right] 11.31$$

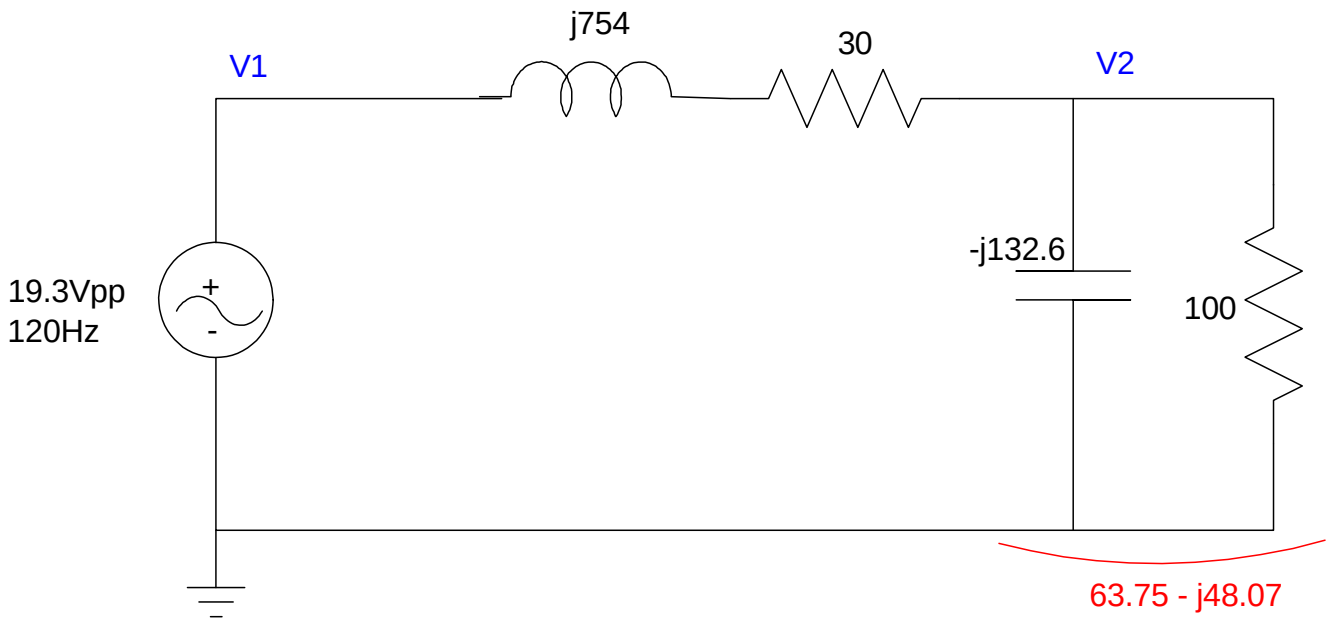
$$_2 = 8.70$$

# AC Analysis:

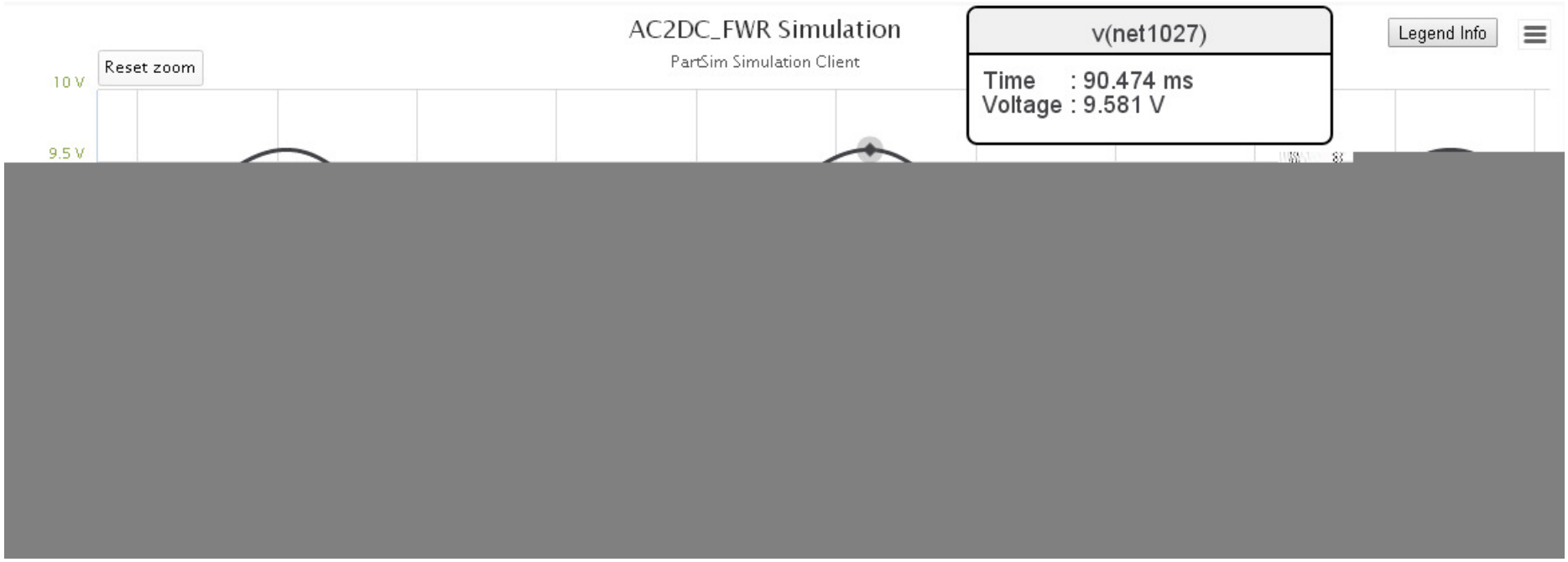
- Convert to Phasors & Solve

$$_2 = \left( \frac{(63.75 \angle -48.07)}{(63.75 \angle -48.07) + (30 + j754)} \right) \cdot (19.3 \ _{pp})$$

$$_2 = 2.164 \ _{pp}$$



# Simulation Results:




| | Calculated V2 | PartSim V2 |
|---|---|---|
| DC Value | 8.70 V | 8.634 V |
| AC Value | 2.164 Vpp | 1.895 Vpp |

## Note:

- The answers are fairly close.  We kept the flavor of the problem
- The answers are a little off.  This isn't surprising since the input isn't a pure sine wave like assumed.

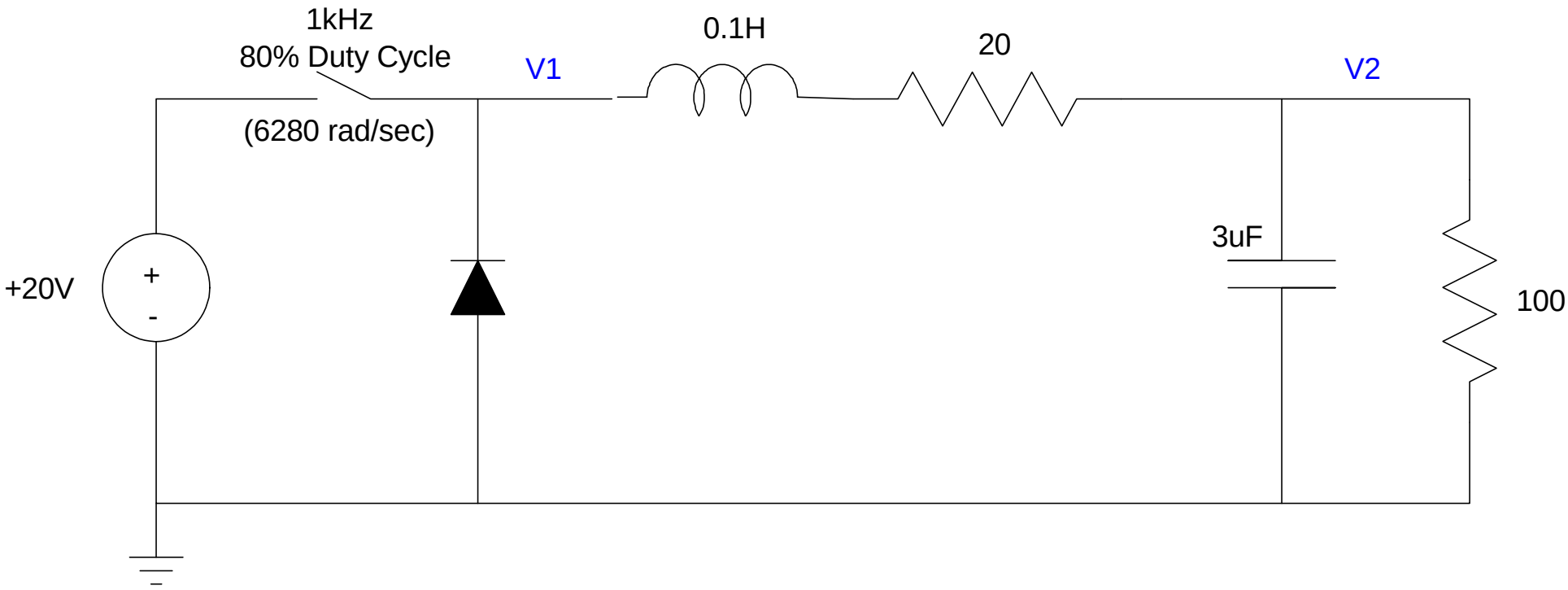
Even though the input is $r$ different from a sine wave, the output is almost a pure sine wave with a DC offset.  This means that treating this as a superposition problem with two terms

- A DC term, and
- A 120Hz term

was a pretty good assumption.

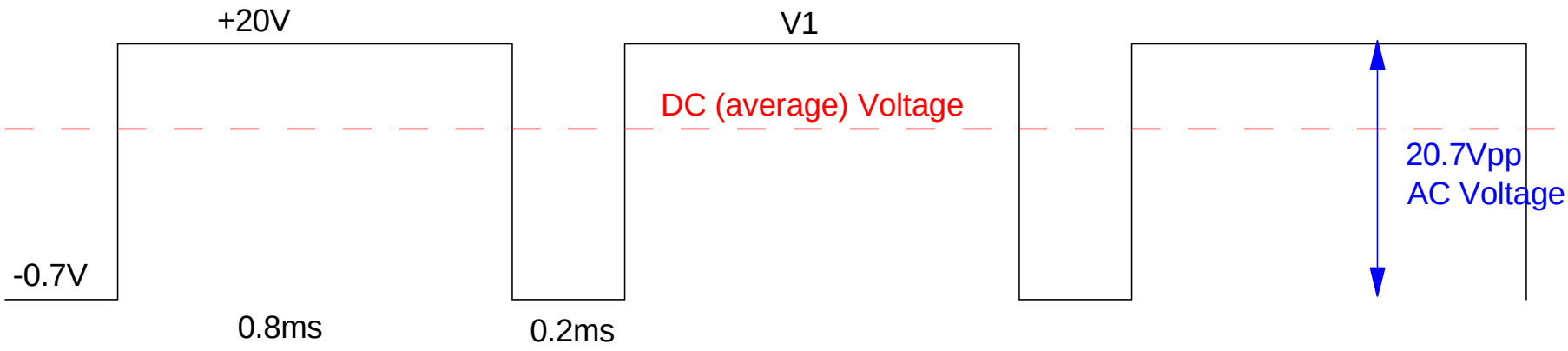
# Example 2: Buck Converter

- Convert 12VDC from a car battery to 5VDC for your cell phone
- Convert 20VDC to 15.8VDC




Example 2: A Buck Converter (covered in ECE 320 Electronics I)

# Problem:  V1 isn't a sine wave




Voltage at V1 with a Buck Converter

Solution: Change the problem so that V1 *s* a sine wave

- Keep the DC value (15.86V)
- Keep the frequency (1kHz)
- Keep Vpp unchanged (20.7Vpp)

$$_1 \approx 15.86 + 10.35 \cos(6280t)$$

# DC Analysis:

$$_1 = 15.86$$

$$_2 = \left[\frac{100}{100+20}\right] \quad _1 = 13.21$$

# AC Analysis (1kHz)

$$_1 = 20.7 \quad _{pp}$$

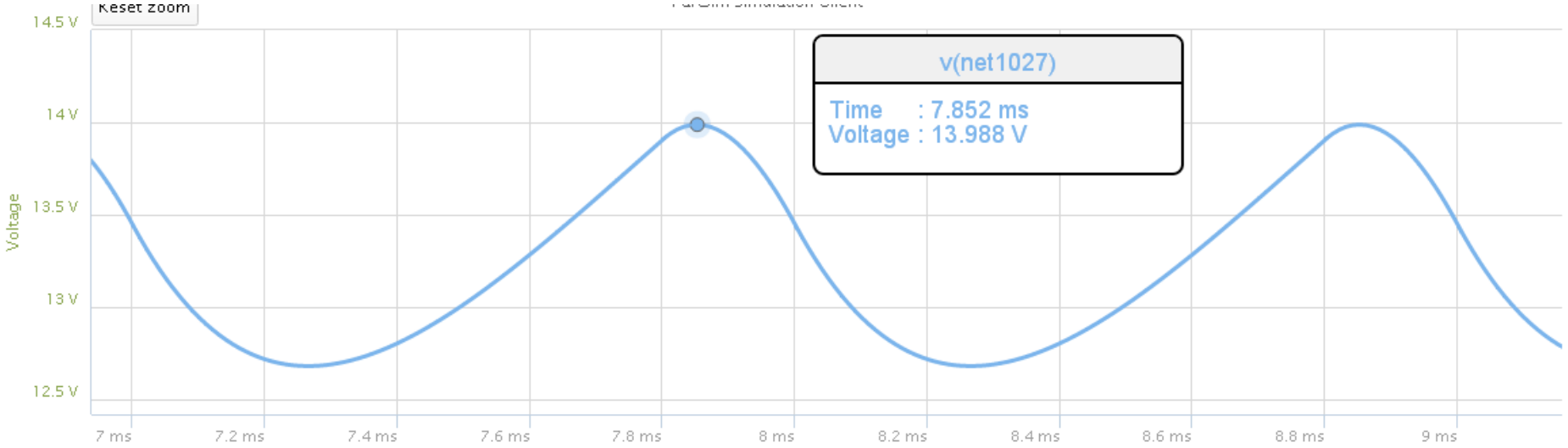
$$_2 = \left| \frac{(21.98 - 41.41)}{(21.98 - 41.41) + (20 + 628)} \right| (20.7 \quad _{pp})$$

$$_2 = 1.65 \quad _{pp} \qquad on \qquad r \qquad o \;\; t \qquad n \;\; t$$

# Simulation Results


V1 (black) and V2 (blue)

# Simulation Results for V2 (expanded)




| | Calculated V2 | CircuitLab V2 |
|---|---|---|
| DC Value | 13.21 V | 13.32 V |
| AC Value | 1.65 Vpp | 1.285 Vpp |

## Summary

Our results are close.  By changing the problem to include

- A DC offset, and
- A sine wave

We were able to

- Solve for V2
- Without significantly changing the results (keeping the flavor of the problem)